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AUTHOR Trembath, Richard J.; Barufaldi, James P.
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ABSTRACT

The present study: (1) identified certain scientific misconceptions possessed by high school and university students; (2) identified, by written and interview means, the origins of these misconceptions; and (3) classified the misconceptions according to their origin. A pilot study using grade 9 high school students showed that, although more time-consuming, a clinical interview yielded more information about the origins of misconceptions than a request for written information about the origins. A final instrument, the Trembath Test of Scientific Misconceptions (TTSM) consisting of 16 true/false items, 15 multiple choice items, and 6 brief written statements, was administered to 47 college students. The TTSM was shown to have a satisfactory reliability. The validity of the test was measured by sampling techniques and by the judgments of a group of science educators. A clinical interview technique revealed the origin of 97.7% of the misconceptions that were detected. The number of semester hours of science taken at grade 10 level correlated positively with the number of misconceptions possessed, and the number of credit hours of science taken in upper division of college correlated negatively with the number of misconceptions possessed. (Author/DS)

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THE FREQUENCIES & ORIGINS OF SCIENTIFIC MISCONCEPTIONS

Richard J Trembath
State College of Victoria at Frankston
Frankston
Victoria
AUSTRALIA

James P Barufaldi
Science Education Center
University of Texas at Austin
Austin Texas
USA

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The Frequencies and Origins of Scientific Misconceptions

Introduction

Although scientific misconceptions were widely studied in the first half of this century (Bailey, 1963; Blanchet, 1952; Caldwell and Lundeen, 1931; Maller, 1941), interest in them has declined in the past 20 years. The possession of scientific misconceptions (e.g., a bird is not an animal) is indicative of scientific illiteracy and is a handicap to citizens of a democratic society who must make judgements on scientific issues, e.g., the use of nuclear energy.

In the present study, the investigation of misconceptions was re-vitalized by

(a) using clinical interview techniques to determine how misconceptions originate and

(b) making a classification of the origin of scientific misconceptions.

Objectives

The first major objective of the present study was to develop a valid and reliable test of scientific misconceptions and to test teacher education students for the possession of these misconceptions. Tests used in earlier studies of misconceptions (e.g., Conklin, 1919, Hancock, 1940) suffered from at least one of these defects: only anecdotal evidence was used to show the existence of the misconception; trivial concepts, superstitition and folklore were tested; only a small number of students was tested (or none at all) or the test did not allow students to answer "I do not know".

The second major objective of the study was to identify the ways in which these misconceptions were acquired (the origins of the misconceptions).

The third major objective of the study was to devise a method of classifying the origins of the misconceptions which could be used reliably by trained classifiers.

Minor objectives included searching for a link between the number of misconceptions possessed by a student and various factors in the educational background of the student, and finding whether differences exist in the numbers of misconceptions possessed by similar groups of American and Australian students.

Procedure

A 37-item test of misconceptions (Trembath Test of Scientific Misconception - TTSM) was devised which selected items from biology, physics, chemistry, health science, astronomy and meteorology. Two pilot forms of the test were devised. Students taking one form of the test were required to write on the test paper the reason why they chose each answer. Students taking the other form of the test were interviewed individually using Piaget's clinical method (Flavell, 1963) by the researcher to find why they chose each answer. On the pilot tests, the clinical interviews, although more time-consuming, revealed the origins of 99% of the misconceptions whereas the written method revealed the origins of only 41% of the misconceptions. Consequently, the clinical interview technique was used in the main investigation.

The final form of the TTSM was administered to 47 science education students at the University of Texas at Austin. After taking the test, 36 of these students agreed to be clinically interviewed. From the protocols of the interviews the researcher developed a system of classification for the origins of misconceptions (Trembath Classification of the Origins of Misconceptions - TCOSM). Two science educators were trained in the use of TCOSM and independently classified ten of the responses drawn at random from the misconceptions revealed.

The TTSM was also administered to a group of science education students at a state college for elementary teachers in Victoria, Australia.

Results

When measured by the Kuder-Richardson 20 formula (Ary, Jacobs & Razavieh, 1972) the reliability of the TTSM was 0.68. Although this value is low when compared with commercially available achievement tests, it is adequate for research in an early stage of development "for which purpose reliabilities of 0.60 and 0.50 will suffice" (Nunnally, 1967, p. 226).

On a Likert-type scale, a panel of five science educators rated the concept being tested in 34 of the 37 items to be important for a scientifically literate citizen to understand. The other items had a rating of "no opinion".

The clinical interviews revealed the origins of 471

(97.5%) of 482 misconceptions which were revealed in the TTSM. Eleven misconceptions were unable to be classified as too little information was revealed in the interviews. The classification system which was devised divided the origins of the misconceptions into six main types and 27 sub-types. A summary of the types and the frequency of response is shown in Table 1.

Table 1

Frequencies of types of origins of misconceptions

Type of origin of misconception	Frequency of type
Quasi misconceptions	
1. Guessed answer	15
2. Misunderstood question while taking test	38
3. Understood question during test, realized answer during interview	0
True misconceptions	
4. Incorrect knowledge of fact being tested	259
5. Incorrect knowledge of subordinate of concept being tested	18
6. Made incorrect logical step	141

These results show that most misconceptions were acquired because learners had either acquired an incorrect knowledge

of a fact being tested or had made a logical error. Of the 259 incorrect facts acquired, 155 were acquired from being told, from reading, from radio/TV/movies or from observation/ experience; while another 104 misconceptions were acquired by a misunderstanding of what had been taught, or by the making of a false assumption about a fact which had not been taught to the learner.

Logical errors were made in 141 responses. Sixty three of these were due to the incorrect or incomplete application of a principle or fact, 23 were due to the making of a tenuous link, 24 were due to incorrect deduction, 5 were due to incorrect induction and 24 were due to errors associated with the mechanics of answering the question.

Of the 10 randomly chosen misconceptions whose origins were classified by 3 classifiers, nine were independently given an identical classification and the tenth was given a slightly different classification by each classifier. As there were 24 possible classifications of the true misconceptions, the possibility of agreement between two classifiers on any one of these classifications is 1 in 24 and the possibility of agreement on nine of the 10 classifications arising by chance is 1 in 3.6×10^{-12}. This shows that the classification system can be used reliably by trained classifiers.

In a study like the present one, it is tempting to seek to link the numbers of misconceptions possessed by students

with all sorts of variables. No correlation was found between the number of misconceptions that a student possesses and the number of semester units of science taken at Grade 11 and Grade 12 levels; the total number of science units taken in Grade 10-12; the number of credit hours of science taken at Lower Division level at College; the number of years he/she has taught (if any) and the grade level he/she has taught (if any). There was a correlation (<.05 level of significance) between the number of misconceptions possessed and the number of semester units of science taken at Grade 10 and the number of credit hours of science taken at Upper Division level.

There was no significant difference between the misconception scores on the TTSM of a group of Texas teacher education students and the scores of a similar group of Australian students.

Conclusion

The present study has introduced a technique - the clinical interview - which is new to the study of misconceptions. It has been shown that the origin of nearly all scientific misconceptions can be traced and reliably fitted into a classification scheme.

This study opens up large new areas of investigation which have scarcely been touched by earlier research. Studies should now be undertaken to systematically classify misconceptions in all sciences at all learning levels, to

find the importance of the presence of scientific misconceptions for subsequent learning, to educate teachers to the misconceptions which their pupils are likely to acquire, and to modify teaching and learning techniques.

Because groups of similar teacher education students displayed similar frequencies for the possession of misconceptions, it would appear that acquisition of misconceptions could be a widespread problem and should be studied over a wide geographic area.

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Nunnally, J.C. Psychometric theory, New York: McGraw-Hill Book Co., 1967.

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Trembath Test of Scientific Misconceptions -- (TTSM)

SCIENCE SURVEY

I want to ask for your help in finding out a little more about how people learn science.

All you have to do is answer the following questions. These questions are to determine your understanding of certain scientific facts and principles. On the basis of your answers some of you will be interviewed.

For each question, choose the best answer.

Be honest -- answer "I don't know" if you do not know.

THANK YOU FOR YOUR HELP.

Richard Trembath

SECTION A -- TRUE/FALSE

USE A CHECK (✓) TO SHOW WHETHER YOU THINK THE FOLLOWING STATEMENTS ARE "TRUE," "FALSE" OR WHETHER YOU "DON'T KNOW."

STATEMENT	TRUE	FALSE	DON'T KNOW
1. During the winter, it is colder inland than it is near the coast.			
2. Boiling kills all bacteria in water.			

STATEMENT	TRUE	FALSE	DON'T KNOW
3. Children born to parents who have always exercised regularly will be genetically superior to children born to the same parents had they not exercised regularly.			
4. The solar system contains only one star.			
5. Hemoglobin makes blood clot.			
6. Cream is less dense than milk.			
7. Tuberculosis can be inherited.			
8. Some bacteria remain alive in milk after it has been pasteurized.			
9. If squirrels gather more nuts, this is an indication that winter will be colder than usual.			
10. If first cousins marry, many of their children will probably be defective or handicapped.			
11. More work can be obtained from a simple machine (e.g., scissors, car jack) than is put into it.			

STATEMENT	TRUE	FALSE	DON'T KNOW
12. Sound waves do not travel through a vacuum.			
13. There is very little hydrogen in the atmosphere.			
14. A planet which is in motion has to be continually acted on by a force or it will cease moving.			
15. Plants take in oxygen (O_2) only at night.			
16. Yeast cells are sometimes created by the fermentation of sweet things (e.g. grapes).			

SECTION B -- MULTIPLE CHOICE

ANSWER THE FOLLOWING QUESTIONS BY PUTTING A CIRCLE AROUND THE LETTER OF THE CORRECT ANSWER.

HERE IS AN EXAMPLE:

Which month follows March?

A. February

B. June

(C) April

D. July

E. I do not know

The circle around C shows your answer

1. Which one of the following is a property of the air which animals breathe out?

   A. It is all carbon dioxide.

   B. It contains the same amount of carbon dioxide as the air around us.

   C. It contains a little more carbon dioxide than the air around us.

   D. It contains a little less carbon dioxide than the air around us.

   E. I do not know.

2. When cooking vegetables in a pan you "turn it down" to a simmer when the water starts to boil. What will happen if you don't do this?

   A. The vegetables will get too hot and burn.

   B. The water will get hotter and boil away too quickly.

   C. The water will not get hotter but it will boil away too quickly.

   D. Too many of the vitamins will be destroyed.

   E. I do not know.

3. If a piece of magnesium is burned, what will be the mass of the magnesium oxide which is formed?

   A. More than the mass of the magnesium which burned.

   B. Less than the mass of the magnesium which burned.

   C. The same as the mass of the magnesium which burned.

   D. Zero.

   E. I do not know.

4. Fish get oxygen through their gills. Where does this oxygen come from?

   A. The fish come to the surface and breathe it in from the air.

   B. Water is made of hydrogen and oxygen and the fish take some of the oxygen the water is made of.

   C. The fish breathe it in when they leap out of the water.

   D. It is dissolved in water (like the way that carbon dioxide is dissolved in "Coca Cola").

   E. I do not know.

5. We have recently moved our clocks one hour up for daylight saving time. What does this mean about the time of sunrise and sunset <u>on our clocks</u>?

   A. The time of sunrise and sunset is an hour earlier.

   B. The time of sunrise and sunset is an hour later.

   C. Sunrise is an hour earlier and sunset is an hour later.

   D. Sunrise is an hour later and sunset is an hour earlier.

   E. I do not know.

6. Food spoils or "goes bad" because bacteria or molds grow in it. Food can be kept fresh in a refigerator because of the low temperature. How does low temperature stop food going bad?

   A. It kills most bacteria and fungi.

   B. It stops the reproduction of bacteria and fungi.

   C. It slows the reproduction of bacteria and fungi.

   D. It destroys the cells of the bacteria and fungi.

   E. I do not know.

7. As you ascend a high mountain in a train or car, what happens to your weight?

   A. It will stay almost exactly the same.

   B. It will get less at first, then more.

   C. It will get quite a bit less.

   D. It will get quite a bit more.

   E. I do not know.

8. If a car runs into the back of a stationary truck, passengers in the car not wearing seatbelts are likely to hit the windscreen of the car. How is this best explained?

   A. The force of the collision throws them forward.

   B. They keep moving as the car slows down.

   C. A force pushes them forward as the car brakes.

   D. The car was going too fast.

   E. I do not know.

9. Two balls have the same diameter as a baseball. One ball is heavy as it is made of steel - the other ball has only half the weight of the steel ball. What will happen if both balls are dropped from a tenth floor window at the same time?

   A. The heavy ball will hit the ground in half the time that it takes for the lighter ball.

   B. The lighter ball will hit the ground long before the heavy ball.

   C. The heavy ball will hit the ground long before the light ball (but not in half the time).

   D. The balls will hit the ground at about the same time.

   E. I do not know.

10. The weather is hotter in the summer than in the winter. Which one of the following explains best why this occurs?

A. The Earth has moved closer to the Sun.

B. The Sun is shining more directly overhead.

C. The length of daylight is longer.

D. Both B and C.

E. Both A and C.

F. I do not know.

11. The Sun rises in the east and sets in the west. How does this happen?

A. The Earth rotates on its axis.

B. The Sun moves around the Earth.

C. The Earth moves around the Sun.

D. The Sun rotates on its axis.

E. I do not know.

12. What causes tides on Earth?

A. The pull of the Moon.

B. The pull of the Sun.

C. The pull of the Sun and Moon.

D. The pull due to the rotation of the Earth.

E. I do not know.

13. Where does most of the material of which a large tree is made come from?

A. Salts from the soil, and water from the soil.

B. Salts from the soil, and carbon dioxide from the air.

C. Water from the soil, and carbon dioxide from the air.

D. Salts from the soil, water from the soil, and carbon dioxide from the air.

E. I do not know.

14. What causes the phases of the Moon?

A. The shadow of the Earth on the Moon.

B. Changes in the reflection from the Moon.

C. Changes in the amount of the lighted half of the Moon which is visible from Earth.

D. The rotation of the Moon on its axis which changes the amount of light reflected to Earth.

E. I do not know.

15. What property must an object have if it will float in water with its top above the surface?

A. It is made of a substance less dense than water.

B. It contains air.

C. It has a volume greater than its mass.

D. It displaces a weight of water equal to its own weight.

E. I do not know.

SECTION C -- BRIEF ANSWER QUESTIONS

ANSWER THE FOLLOWING QUESTIONS BY WRITING A BRIEF STATEMENT. IF YOU DO NOT KNOW THE ANSWER, WRITE "I DO NOT KNOW". DRAW A DIAGRAM IF YOU FEEL IT MAY HELP YOU ANSWER A QUESTION.

1. A jet aircraft engine ejects hot gases from the rear of the engine. How does this blast of hot gas make the aircraft move forward?

2. Food placed in a portable icebox (cooler) remains cold as long as ice remains in the box. How does ice keep the contents of the box cold?

3. How can the development of the long neck in giraffes be explained by evolutionary theory?

4. List the two most abundant gases in the air.

   Most common _____

   Next most common _____

5. Name the main substance(s) manufactured by a plant when it combines carbon dioxide and water.

   _____

6. What is an insect?

   _____

   _____

   _____

Pro-forma Used for Interviews

NAME ..... QUESTION .....

Did you guess this answer?	YES	
Did someone tell you this answer sometime? Mother Father Sister Brother Age ..... Older/Younger Teacher Grade ..... Other	YES	
Did you read this somewhere? Book Comic Newspaper Other	YES	NO
Did you learn this from television? radio? Name of show	YES	NO
Is this the result of your own observation?	YES	NO
Did you just work this out for yourself?	YES	NO